Future Changes in Gulf of Mexico Hurricane Waves

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Introduction

In support of societal demand for assessments of future changes in Gulf of Mexico hurricane impacts, we investigate potential future changes in significant wave height under projected storm intensities. Ten historical Gulf of Mexico hurricanes (Fig. 1) are simulated using the Coupled Ocean Atmosphere Wave Sediment Transport (COAWST) modeling system.

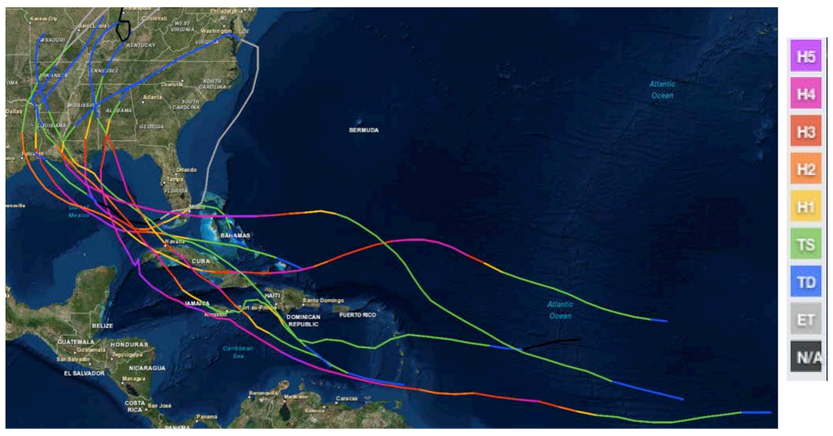


Fig.1. Tracks of the 10 case study hurricanes: Andrew (1992), Lili (2002), Ivan (2004), Dennis (2005), Katrina (2005), Rita (2005), Gustav (2008), Ike (2008), Ida (2009) and Isaac (2012) (figure generated at: coast.noaa.gov/hurricanes/).

Methodology

Define the Wind Forcing

The wind forcing used for the ocean-wave simulation is derived from merging the Real-Time Hurricane Wind Analysis (HWIND) and the NCEP North American Regional Reanalysis (NARR, to fill in the wind field in surrounding environment). Figure 2 shows the impact of merging HWIND with NARR for the case of hurricane Katrina. HWIND captures smaller scale hurricane structure and higher maximum wind speeds than NARR alone.

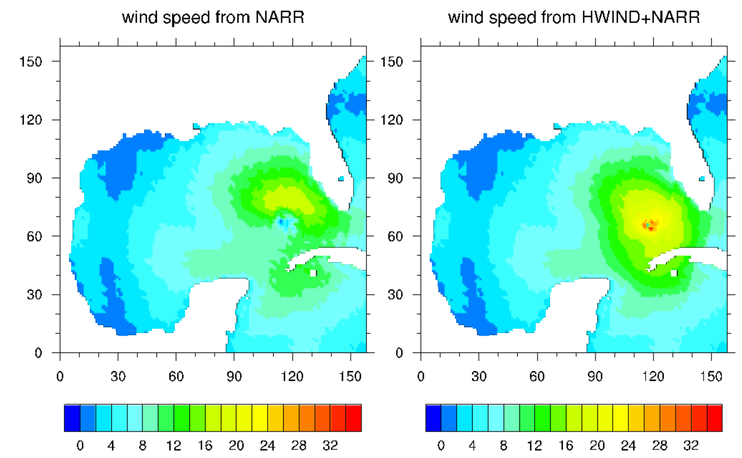
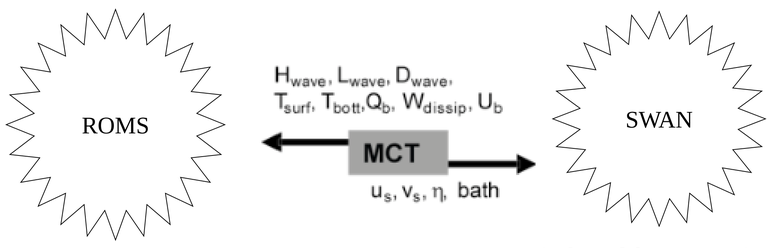


Fig. 2. Snapshot of wind speed for Hurricane Katrina using (left) NARR, and (right) H*WIND combined with NARR.

ROMS<->SWAN Modeling System



(Adapted from USGS).

ROMS	SWAN
dx=12 km	Whitecapping
159x159 grid	Quadruplet wave interactions
16 vertical sigma layers	Depth-induced breaking
BC's from HYCOM	BC's from WAVEWATCH III
GLS turbulence closure	Jonswap bottom friction

Hurricane Waves under Future Scenarios

To assess future hurricane waves, future hurricane wind fields are generated and used to drive the wave-ocean model. Three future scenarios are; a 10% increase in hurricane wind speed, a 10% reduction in hurricane size, and both +10% wind speed and -10% size.

Figure 3 shows the impact of the future climate scenarios on significant wave height for Hurricane Lili (2002). Changes are in the expected direction with the more intense hurricane increasing the significant wave heights and the smaller hurricane decreasing wave heights.

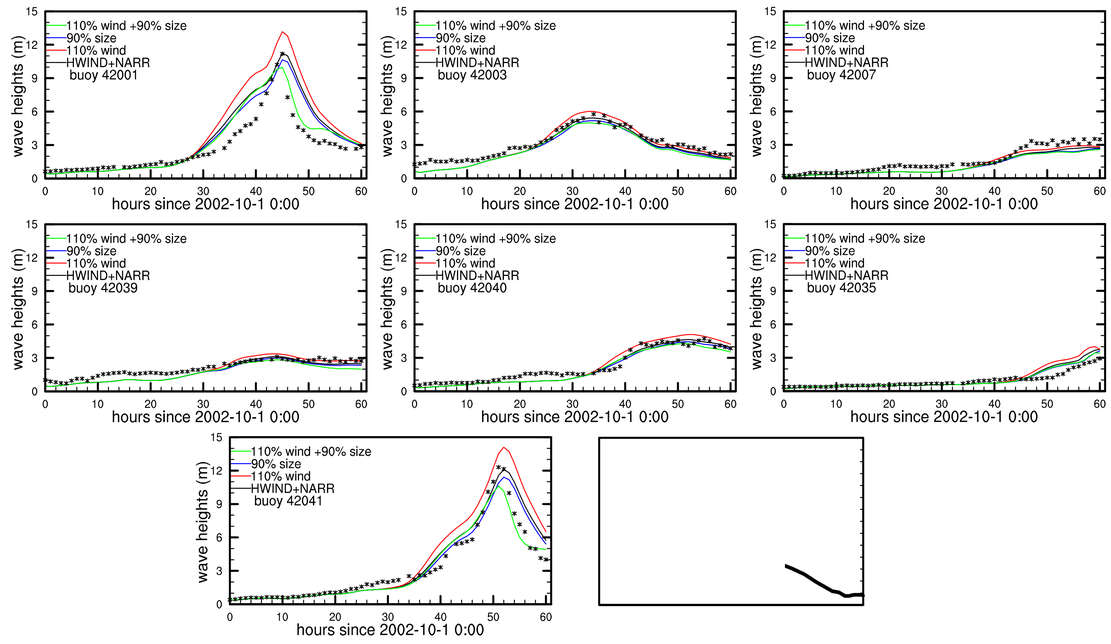


Fig. 3. Time series of significant wave height (m) during Hurricane Lili (2002) at selected buoy locations for (black stars) buoy observations, (black line) using observed winds, and three future climate scenarios: (red line) 10% increase in wind speed, (blue line) 10% decrease in size, and (green) 10% increase in wind speed and 10% decrease in size. The track of Lili and buoy locations are shown in the bottom right plot.

Offshore structures are vulnerable to combinations of atmospheric and oceanic variables. An example analysis of two variables is shown in Fig. 4 for significant wave height and wave period. There is a high degree of correlation in hurricane environments.

High percentile values are calculated by fitting Weibull distributions to the dynamically simulated distributions and the results are shown as red dots on Fig. 4. Under the future scenario of +10% wind speed and -10% size the distribution shifts to higher wave heights and longer wave periods with the largest proportional increases at the highest percentiles.

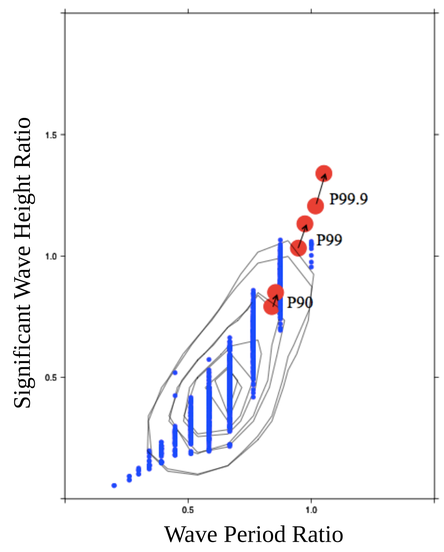


Fig.4. Relationship between significant wave height ratio and wave period ratio over all 10 historical hurricanes under current and future climate scenario of +10% winds and -10% size. The ratio is the absolute value divided by the maximum value in current climate.

Blue dots show data taken from the location of the maximum significant wave height every hour through the simulations of the 10 case studies, black contours indicate the density of the blue dots, and the red dots show the 90th, 99th and 99.9th percentile values (P90, P99 and P99.9, respectively).

Significant wave height and wave period analysis is shown in Table 1. The high percentiles show future increases of up to 10%.

	P90	P99	P99.9
Wave Period	+2	+3	+3
Significant wave height	+7	+10	+10

Table 1. Percent future changes in the extreme values.

Summary

The future scenario of increased wind speed and decreased size applied to historical hurricanes leads to overall increases in hurricane wave activity, with the biggest proportional increase in the significant wave height.

References

Warner, J.C., Sherwood, C.R., Signell, R.P., Harris, C., Arango, H.G., 2008. Development of a three-dimensional, regional, coupled wave, current, and sediment-transport model. Computers and Geosciences, 34, 1284-1306